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Assessment Of Forest Fragmentation Mapping And Predictive Modelling Using Landsat Data Of Goalpara District, Assam

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Abstract:
Forest land is primarily comprises with diversities of trees species and have significant forest canopy, which is crucial part of our environment and primary habitat area for many terrestrial ecosystem. But at time of rapid urbanization, industrialization, and globalization the forest land is highly effected on these natural ecosystem. As result the naturally forest cover area breaking down into small patches or disrupted from from core area. To understanding the issues in Goalpara district, where small fragmentation and isolated forest area are highly changing over time and well known habitat area for of Asian elephant the present studies were carried out with Landsat imagery (i.e.1993, 2003, 2013, and 2023) through landscape fragmentation tools (LFT) using GIS environment. The forest fragmentation predictive mapping were also performed to know future estimation (2033) of forest cover change using Artificial neural network (ANN), and Cellular automata (CA) simulation in QGIS software.
The significant outcomes of the study are in last 30 years the district loss forest cover 33.38 sq.km (i.e.1993-2023) with 1.09 sq.km per year and it will accelerate at 9.20 sq.km per year till 2033. Whereas the positive r square value (r^2 = 0.34) determine that the forest cover area will constantly decline at current trend in upcoming days. While the fragmentation mapping (1993-2033) depicted that out of six classes namely- Patch, Edge, Perforated and Core(Large<500, Medium 250-500, and small <250 acres), most of the transitional changes are found in the class between of edge to patch (25.13sq.km), large core to perforated (13.48 sq.km), medium to small core (4.77 sq. km), patch to edge (33.99 sq.km), perforated to edge (20.26 sq. km.), small core to edge (13.52 sq. km).

1. INTRODUCTION:

Forests are essential components of our ecosystem, providing humanity with various goods and services. However, significant exploitation and human interaction, resulting from urbanization, economic development, alterations in land use and land cover (LULC), and population growth, pose substantial concerns for the sustainability of natural ecosystems (Biswajit Bera et al., 2020). The loss and degradation of forest cover have resulted in the fragmentation of natural forests into small patches, which adversely affects habitat area, leads to biodiversity extinction, and alters wildlife movement corridors, consequently resulting in conflicts (Vogt et al., 2007, Saha Ranjana & Datta Chandan, 2017). Forest fragmentation and habitat loss are critical issues and regarded as important challenges in global biodiversity conservation (Midha and Mathur, 2010). The swift fragmentation of forests disrupted natural corridors that connect habitat areas, hence affecting the dispersal and migration of individuals between habitat islands for sustenance, shelter, reproduction, and other activities (Khanna et al., 2001).

The accurate measurement is crucial as resources are subject to geographical and temporal variations owing to human interaction, resulting in gradual degradation that directly and indirectly affects the forest ecosystem. Spatio-temporal remote sensing data facilitate the analysis of dynamic complex interactions within landscapes, particularly through the evaluation of forest fragmentation changes. Identify the rising fragmentation rate that results in deforested areas and non-forest land, while including all local stakeholders to mitigate forest encroachment and promote regeneration activities (TV. Ramachandra et al., 2016). This is also applicable in forest cover prediction and vulnerability identification using various geospatial approaches, such as the Random Forest-Cellular Automata Modeling Approach (Cohen's kappa coefficient similarity index test), artificial neural networks (ANN), and Markov chain models to analyze forest conversion, which are typically employed to examine nonlinear relationships between variables in a GIS environment (Lv, J et al. 2021). The primary objectives of this application are the identification of deforestation and its potential changes based on various anthropogenic variables, including settlement density, proximity to settlements, physiographic factors (elevation), bioclimatic factors (mean annual temperature, isothermality, annual precipitation, etc.), and land use and land cover parameters (Saleh, Arekhi, et al., 2014; Irmadi Nahib and Jaka Suryanta, 2017).

2. Study Region:

Goalpara district has high ecosystem service value (ESV), which comes from various ecosystem specially forest ecosystem which is situated in the western region of Assam and encompasses a geographical area of 1824 km^2. Geographically extension of the study area is located between the latitudes of $25^0$53'—$26^0$30' north and the longitudes of $90^0$7'—$91^0$5' east. The district falls under Goalpara forest division with comprise with four forest ranges, i.e. Lakhipur, Goalpara Sadar, Central range (Krishnai), and Rangjuli range. Geographically, the Rangjuli range covers the largest area with an area of approx. 553.11sq.km followed by Lakhipur(509.68sq.km), central range(388.48sq.km) and Goalpara Sadar (372.55sq.km). Besides this, the division has also a total of 29 forest blocks, and One Divisional Forest Office (DFO) is in Goalpara town, and each range has many local beat offices (BO) located in different parts of particular ranges (https://forest.assam.gov.in/).

The district has rich natural resource such as soil, water, forest biodiversity (flora and fauna), minerals (sand, rocks gypsum, granite and quartzite etc.) as well as socio-cultural heritage. In the district there are found about 700 species of angiospermic plants, of which 427 species belong to dicotyledonous group (Nath, 2006). Again, the study area having a total of 55 RF and 48 PRF (Medhi and Kar, 2016) and a lot of unclassed forest. But the in the last research indicating that forest area is decreasing annually at the rate of 0.64%, which is great concerned (Deka, Sangeta et al. 2019). This is because of forest area decreased from 389 sq. km in 1999 (21.33%) to 337 sq. km. in 2011(18.48%) (Rabha, Kr. Bipul, 2016).

3. Objectives:

The main objective present study are:

1. To mapping and detecting the spatio-temporal forest fragmentation in Goalpara district since 1993-2023.
2. To assess the forest cover and fragmentation change analysis using Landsat imagery and
3. To analyse the forest cover predictive modelling Artificial neural network.

4. DATABASE AND METHODOLOGY:

To understand the spatial distribution forest cover pattern for the periods of 1993-2023, Landsat satellite imagery were collected from USGS earth explorer (https://earthexplorer.usgs.gov/) for the year 1993, 2003, 2013 and 2023(January-march) using visible wavelengths (i.e. RGB and NIR) spatial resolution 30 m . Further supervised classification algorithms were performed to classify LULC with appropriate 10 classes in Arc GIS software v.10.3 (i.e., water bodies (WB), sandbars (SB), barren land (BL), cropland (CL), agricultural plantation (AP), dense forest (DF), moderate forest (MF), open forest (OF), built-up area (BU), and low-lying area (LL). From the LULC classes further classified as Forest Cover and Non-Forest Cover, where AP, DF, MF, OF categories into forest and other classes were classified into non forest cover (Verma, P., et al. 2020).

However, predictive modelling were done through MOLOUSE plugin tools in Q GIS software v. 3.44.1 using Artificial neural network (ANN) and Cellular automation simulation (CA) with run base on LULC classified image with spatial variables like distance from major roads, distance from minor roads, elevation, slope, population density, distance from town, rainfall etc.

Again, Forest fragmentation classification was proceed through landscape Fragmentation analysis tools in Arc GIS with six classes namely patch, edge, perforated, small core, medium core and large core. The summary of forest fragmentation types as explain below:

FOREST FRAGMENTATION TYPES	DESCRIPTION

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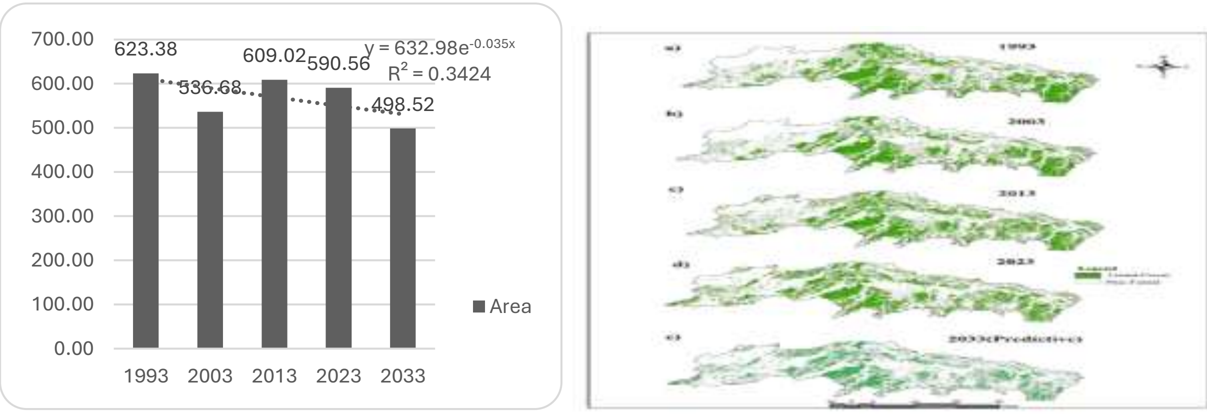
PATCH	Small isolated area of forest surrounding the various non forest landscape. A class with greater density of patches indicate that it is subdivided into many patches and thus could be considered more fragmented.
EDGE	The outside boundary of a core forest area and high change forest fragmentation. Where, amount of edge relative to total area is expected to increase in initial stages of fragmentation.
PERFORATED	Forest fragmentation characterized by the presence of relatively small non forest areas within a larger forest area, creating a network of forest and non-forest patches.
SMALL CORE	Forest Cover with less than 250 acres, Forest area that distinguish between near to the forest edge and larger forest area.
MEDIUM CORE	Forest Cover with between 250-500 acres, that is unfragmented forest areas located far from the edge of the forest.
LARGE CORE	Forest Cover with larger than 500 acres with unfragmented and interior parts of the forest land.

5. RESULT AND DISCUSSION:

5.1 Forest Cover Change analysis:

The landscape pattern on the Earth's surface is very dynamic and undergoes shifts in time. The current findings indicate that the forest cover in the Goalpara district has undergone considerable changes throughout time, as illustrated in figures 1-2. The total forest cover area is recorded as 623.38 sq.km (34.17%) in 1993, 536.39 sq.km (29.40%) in 2003, 609.02 sq.km (33.38%) in 2013, 590.56 sq.km (32.37%) in 2023, and is projected to be 498.52 sq.km (27.33%) in 2033. The results unequivocally indicated that from 1993 to 2003, the study area experienced a forest area reduction of -86.99 sq.km (-13.95%). Conversely, from 2003 to 2013, there was a positive change with an increase of 72.63 sq.km (+13.54%). Subsequently, from 2013 to 2023 and from 2023 to 2033, the forest area diminished by -18.46 sq.km (-3.12%) and -92.06 sq.km (-15.59%), respectively. Conversely, throughout a 30-year period, the study region had a reduction in forest cover at a rate of 1.09 sq.km annually, resulting in an anticipated drop of 9.20 sq.km by 2033. The positive R-squared value (r^2 = 0.34) indicates that the forest cover area will consistently diminish under the current trend in the forthcoming days.

igure1: Forest Cover map from 1993-2033(Predictive) and area



5.2 Forest Fragmentation Analysis:

In recent years, forest habitats have been fragmented for various reasons across different regions of the globe. Various approaches have been developed to quantify spatio-temporal extensions of the Earth. This technique classifies forest areas into four distinct zones: Patch, Perforated, Edge, and Core, each with a 100-meter edge width. The Centre for Land Use Education and Research (CLEAR) developed version 2.0 of the fragmentation tool (LFT). This spatial analysis tool categorized the raster forest data into four distinct classifications: Patch, Edge, Perforated, and Core (Fig. 6). The core is categorized into three significant classes: high core (> 500 acres), middle core (250–500 acres), and low core (< 250 acres).

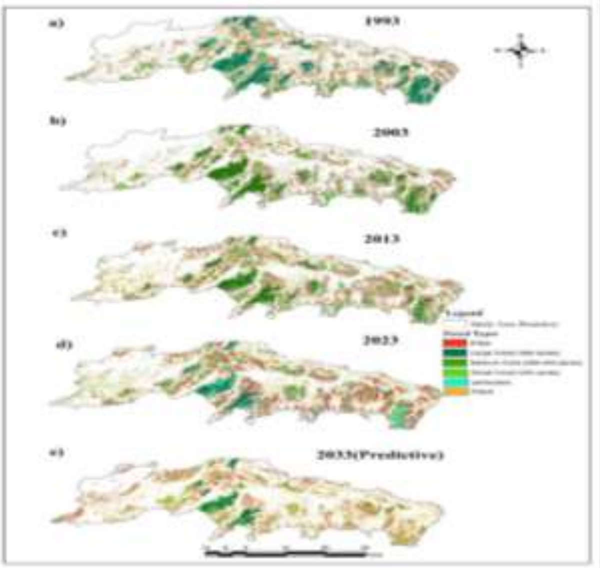


Figure 2: Forest fragmentation from 1993-2033, a) Fragmentation map 1993, b)Fragmentation map 2003, c) Fragmentation map 2013, d) Fragmentation map 2023, and e) Fragmentation map 2033 (Predictive)

5.3 Assessment of Forest Fragmentation:

5.3.1 Change in 1993-2003 period:

In this period, the largest forest fragmentation class was observed in tiny core areas, with a gain of 0.60 sq.km. Conversely, negative changes (losses) were recorded in the perforated category at -28.47 sq.km, followed by patch areas at -21.10 sq.km, edge areas at -17 sq.km, and big core areas at -16 sq.km. Additionally, non-forest areas experienced a gain of 86.7 sq.km. This conclusion indicates that extensive forest areas and permanent interior forest landscapes have been reduced to fragmented forest land. The forest cover located outside the designated areas (outside RF/PRF) has diminished due to alterations in land use and land cover (LULC) within the research region.

5.3.2 Change in 2003-2013 period:

Between 2003 and 2023, the overall forest area exhibited a considerable increase, with forest cover in the study region expanding by approximately 72.34 square kilometers. Similar to the forest fragmentation recorded from 1993 to 2003, there was a substantial loss of core area amounting to -35.56 sq.km, accompanied by an increase in non-forest area of -72.4 sq.km. Conversely, a positive shift was noted in the forest edge category, totaling 66.22 sq.km, followed by a 10 sq.km increase in forest patches. Core area of 22.21 square kilometers, with a perforated forest of 7.69 square kilometers. The results indicate that fragmentation has significantly increased compared to previous periods. In 2003, the large core covered an area of 140.54 (26.19%), the medium core covered 17.15 (3.20%), and the small core covered 70.11 (13.06%). Additionally, there was a forest edge area of 184.11 (34.3%) and forest patches of 62.15 (11.58%). The large core subsequently measured 104.98 (17.24%), the medium core 18.92 (3.1%), and the small core 92.32 (15.16%). Conversely, the area of forest edge increased to 250.34 (41.10%) and forest patches to 72.19 (11.85%).

5.3.3 Change in 2013-2023 period:

Between 2013 and 2023, a positive change has been observed in areas covering 108 sq. km. Perforated area measures 30.50 sq.km, while other negative changes have been observed in the classes: small core at 58.8 sq.km, edge at -55.21 sq.km, and medium core at -10.73 sq.km. From 2013 to 2023 the total forest cover loss amounted to 18.46 sq.km. The large core area decreased from 104.98 sq.km (17.24%) to 46 sq.km (7.58%), while the medium core area reduced from 18.92 sq.km (3.11%) to 8.9 sq.km (1.34%). The small core area was recorded at 92.32 sq.km (15.16%). The area decreased from 37.11 sq.km (6.09%) while other classes such as forest edge, patch, and perforated experienced changes from 250.34 sq.km

(41.10%) to 236.26 sq.km (38.76%), 72.19 sq.km (11.85%) to 181.04 sq.km (29.70%), and 70.27 sq.km (11.54%) to 100.77 sq.km (16.53%), respectively.

5.3.4 Change in 1993-2023:

Analysis of the period from 1993 to 2023 reveals a significant decline in forest cover, with a rate of -1.09 sq.km per year. Notably, major fragmentation of forest types has been documented, highlighting a substantial loss in large core areas amounting to -111.22 sq.km, alongside losses in small core areas of -32.41 sq.km and medium core areas of -10.73 sq.km. In contrast, the other fragmentation classes show an area of 34.29 sq.km for forest edge, 97.80 sq.km for patch, and 9.68 sq.km for perforated. This result indicates that during this time period, the forest landscape, particularly in the core areas, has experienced loss and fragmentation into smaller patches.

Table 1: Forest fragmentation types and area change for the 1993, 2003, 2013, 2023, and 2033

	1993		2003		2013		2023		2033(Predictive)		Change (sq.km)					
Forest Types	sq.km	%	sq.km	%	sq.km	%	sq.km	%	sq.km	%	1993-03	2003-13	2013-23	2023-33	1993-23	1993-33
Edge	201.97	32.40	184.11	34.31	250.34	41.10	236.26	38.76	168.16	33.73	-17.86	66.22	-14.07	-68.11	34.29	-33.81
Large core	157.40	25.25	140.54	26.19	104.98	17.24	46.18	7.58	52.37	10.51	-16.85	-35.56	-58.80	6.19	-111.22	-105.03
Medium core	20.16	3.23	17.15	3.20	18.92	3.11	8.19	1.34	13.62	2.73	-3.01	1.76	-10.73	5.43	-11.97	-6.54
Patch	83.24	13.35	62.15	11.58	72.19	11.85	181.04	29.70	126.87	25.45	-21.10	10.05	108.85	-54.17	97.80	43.63
Perforated	91.09	14.61	62.62	11.67	70.27	11.54	100.77	16.53	86.26	17.30	-28.47	7.65	30.50	-14.51	9.68	-4.83
Small core	69.52	11.15	70.11	13.06	92.32	15.16	37.11	6.09	51.24	10.28	0.60	22.21	-55.21	14.13	-32.41	-18.28
Non-Forest Area	1200.6	65.82	1287.3	70.57	1214.9	66.60	1233.43	67.62	1325.4	72.66	86.7	-72.4	-18.53	91.97	32.83	124.8
Total Forest	623.38	34.17	536.68	29.42	609.02	33.39	590.56	32.37	498.52	27.33	-86.7	72.34	-18.46	-92.04	-32.82	-124.86

5.3.5 Change in 1993-2023:

Over a span of 30 years, from 1993 to 2023, the analysis revealed a decline in forest cover at a rate of -1.09 sq.km annually. Significant fragmentation of forest types was noted, with a substantial loss in large core areas amounting to -111.22 sq.km, followed by small core areas at -32.41 sq.km, and medium core areas at -10.73 sq.km. In contrast, the other fragmentation class shows an area gain of 34.29 sq.km for forest edge, 97.80 sq.km for patch, and 9.68 sq.km for perforated. This result indicates that during this time period, the forest landscape, particularly in the core areas, has been experiencing loss and fragmentation into smaller patches.

5.3.6 Change in 2023-2033 period (predictive):

In this period, forest cover predictive chance of change was assessed and found drastically forest loss around an area of -124.86 Sq.km. In fragmentation class highest change highest change have been observed in the classes of large core, small core, medium core with a positive change about an area of 6.19 sq.km, 14.13sq.km, 5.43 sq.km respectively. While the negative change has been found the classes of -68.11 sq.km in forest edge, -54.17 sq.km in forest patch, -14.51 sq.km in perforated forest. This due to overall cover change was detect with and area of -92.04 sq.km where small forest edge and patch and extinct from the present forest cover till 2033.

5.3.7 Change in 1993-2033 period(predictive):

By 2033, a span of over 40 years since 1993, the study area is projected to lose approximately 54.05% (336.98 sq.km) of its previously occupied forest land. The fragmented forest area, including large core (-105.03 sq.km.), edge (-33.81 sq.km), small core (-18.28 sq.km), and medium core (-6.56 sq.km), is expected to decrease. The increase will occur solely within the forest patch class that encompasses an area of 43.63 sq.km. The most significant change has been observed in the classes of large core area, which was 157.40 sq.km (25.25%) in 1993, and is projected to decrease by 46.18 sq.km (7.58%). Conversely, the forest patch area is expected to increase by up to 126 sq.km (25.45%). Subsequently, it is evident that the interior or core of the forest landscape is undergoing a transformation into non-forest areas and fragmented forest patches.

5.4.1 Overall Dynamic Transition changes Analysis:

Transition change assessment aids in identifying the dynamic evolution of features throughout time. The table illustrates the transitions of forest fragmentation types across several time cycles, with bold black text indicating the most significant consistent area changes within the same class, while red text signifies transitions between distinct classes.

5.4.2 Transition change in 2003-2013:

Between 1993 and 2003, the most significant change seen was from edge to patch (12.69 sq.km), with a total change within the class of 67.92 sq.km. In the case of big core, the highest shift was from large core to perforated (16.59 sq.km), while the change within the same class amounted to 107.51 sq.km. Medium to small core (5.34 sq. km), patch to edge (11.01 sq. km), patch to patch (11.01 sq. km), perforated to large core (18.55 sq. km), perforated to perforated (15.67 sq. km), small core to edge (15.17 sq. km), and small core to small core (23.93 sq. km).

5.4.3 Transition change in 2003-2013:

Between 2003 and 2013, significant transitional changes were observed: edge to small core (16.73 sq.km), edge to edge (87.06 sq.km), large core to perforated (16.39 sq.km), large core to large core (84.18 sq.km), medium to large core (3.78 sq.km), medium core to medium core (4.94 sq.km), patch to patch (12.91 sq.km), and small core to edge (16.17 sq.km).

5.4.4 Transition during 2013-23:

In this cycle, the significant transition changes identified include edge to patch (90.81 sq.km), edge to edge (149.48 sq.km), large core to perforated (26.01 sq.km), and large core to large core (46.18 sq.km). Medium core to small core: 8.88 sq.km; medium core to medium core: 0.51 sq.km. Patch area: 72.17 sq.km; perforated area: 41.42 sq.km; small core to edge area: 46.90 sq.km; small core area: 16.09 sq.km.

Table 2: transitional changes of forest fragmentation classes from 1993-2033

Transition change	1993-03	2003-13	2013-23	1993-23	2023-33
edge to edge	**67.92**	**87.06**	**149.48**	**57.34**	**64.01**
edge to large core	3.92	3.69	-	0.54	1.18
edge to medium core	1.71	1.64	-	0.58	0.55

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edge to patch	**12.69**	8.30	**90.81**	**37.99**	**25.13**
edge to perforated	9.00	11.87	9.56	9.56	18.11
edge to small core	12.30	**16.73**	-	1.88	4.71
large core to edge	12.92	11.88	12.50	34.77	2.18
large core to large core	**107.51**	**84.18**	**46.18**	**39.39**	**33.42**
large core to medium core	4.57	7.97	8.19	4.67	-
large core to perforated	**16.59**	**16.39**	**26.01**	**40.90**	**13.48**
large core to small core	5.63	11.03	12.10	16.37	1.63
medium core to edge	3.09	1.91	5.47	6.54	3.75
medium core to large core	3.18	3.78	-	-	-
medium core to medium core	**3.71**	**4.94**	-	**0.51**	**0.98**
medium core to perforated	2.37	1.68	4.57	5.50	2.77
medium core to small core	**5.34**	**3.46**	**8.88**	4.07	4.77
patch to edge	**11.01**	16.62	0.00	**9.33**	**33.99**
patch to patch	**12.19**	**12.91**	**72.17**	**20.51**	**38.39**
patch to perforated	0.86	1.35	-	1.32	6.99
patch to small core	1.41	2.19	-	0.24	1.23
perforated to edge	**18.08**	**15.52**	**20.89**	**25.69**	**20.26**
perforated to large core	**18.55**	8.22	-	4.91	8.03
perforated to medium core	2.07	1.64	-	0.93	3.76
perforated to perforated	**15.67**	**13.65**	**41.42**	**17.90**	**22.51**
perforated to small core	10.84	9.12	-	4.50	10.62
small core to edge	**15.17**	**16.17**	**46.90**	**25.51**	**13.52**
small core to large core	2.17	1.62	-	0.07	1.04
small core to medium core	3.88	0.96	-	0.83	1.34
small core to perforated	7.41	9.62	18.66	8.20	8.09
small core to small core	**23.93**	**31.52**	**16.09**	**6.24**	**6.78**

Note:

5.4.5 Transition change in 1993 to 2023:

The primary alteration observed over the past thirty years includes the transition from edge to patch (37.99 sq.km), large core to perforated (40.90 sq.km), medium to edge (6.54 sq.km), patch to edge (9.33 sq.km), perforated to edge (25.69 sq.km), and small core to edge (25.51 sq.km).

5.4.6 Transition change in 2023-2033:

Similar to the previously discussed periods, significant alterations in forest fragmentation types are observed in the following categories: edge to patch (25.13 sq.km), large core to perforated (13.48 sq.km), medium to small core (4.77 sq.km), patch to edge (33.99 sq.km), perforated to edge (20.26 sq.km), and small core to edge (13.52 sq.km).

The analysis of forest fragmentation transition clearly indicates that the fragmentation class is changing, specifically between two constant classes: changes occurring within the same class and transitions from one class to another. The changes observed between specific classes exhibit a degree of similarity. These changes are frequently noted in the transitions from edge to patch, large core to perforated, medium core to small core, patch to edge, perforated to edge, and small core to edge.

6. CONCLUSION:

Mapping forest fragmentation is fundamental for landscape ecological research, facilitating the assessment and analysis of diverse patterns and changes in landscapes. This is crucial in detecting habitat appropriateness, animal corridor migration, and the overall impact of forest environments. It will also be beneficial to evaluate pressing concerns such as the men-elephant conflict inside the research region. The data clearly indicates that forest fragmentation in the study area is transitioning from extensive core wooded regions to smaller patches and non-forested areas. Consequently, it is emerging as a significant issue for various stakeholders, including conservators, government agencies, and local entities. Predictive modeling indicates that the forest area will diminish by 92.04 sq. km between 2023 and 2033. Consequently, a comprehensive conservation program and investigation are indeed necessary to sustain or manage forest conservation and to restore forest ecosystems.

REFERENCES:

❖ Biswajit Bera, Soumik Saha & Sumana Bhattacharjee. 2020, Estimation of Forest Canopy Cover and Forest Fragmentation Mapping Using Landsat Satellite Data of Silabati River Basin (India), 2020, - Journal of Cartography and Geographic Information (2020) 70:181–197 https://doi.org/10.1007/s42489-020-00060-1
❖ Kozak, J., Estreguil, C., & Vogt, P. (2007). Forest cover and pattern changes in the Carpathians over the last decades. *European Journal of Forest Research*, *126*(1), 77-90.
❖ Saha Ranjana, Datta Chandan, 2017, Analysing Land Use/Land Cover Changes, Prediction and Fragmentation in Jaldapara-Buxa Forest and its Corridor, West Bengal, India, Using Geoinformatics, 2017, International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887 Volume 5 Issue XII December 2017- Available at www.ijraset.com
❖ Midha, N. and Mathur, P.K. (2010) Assessment of Forest Fragmentation in the Conservation Priority Dudhwa Landscape, India Using FRAGSTATS Computed Class Level Metrics. Journal of the Indian Society of Remote Sensing, 38, 487-500. http://dx.doi.org/10.1007/s12524-010-0034-6
❖ Khanna, Jaya, David Medvigy, Stephan Fueglistaler, and Robert Walko. "Regional dry-season climate changes due to three decades of Amazonian deforestation." *Nature Climate Change* 7, no. 3 (2017): 200-204.
❖ TV. Ramachadra , Setturu Bharath and Chandran Subash (2016), Geospatial analysis of forest fragmentation in Uttara Kannada District, India, Forest Ecosystems (2016), 3:10 DOI 10.1186/s40663-016-0069-4
❖ Lv, J., Wang, Y., Liang, X., Yao, Y., Ma, T., & Guan, Q. (2021). Simulating urban expansion by incorporating an integrated gravitational field model into a demand-driven random forest-cellular automata model. *Cities*, *109*, 103044.
❖ Arekhi, S., & Jafarzadeh, A. A. (2014). Forecasting areas vulnerable to forest conversion using artificial neural network and GIS (case study: northern Ilam forests, Ilam province, Iran). *Arabian Journal of Geosciences*, *7*(3), 1073-1085.
❖ Saleh, Arekhi., Ali, Akbar, Jafarzadeh. (2014). Forecasting areas vulnerable to forest conversion using artificial neural network and GIS (case study: northern Ilam forests, Ilam province, Iran). Arabian Journal of Geosciences, 7(3):1073-1085. doi: 10.1007/S12517-012-0785-1
❖ Irmadi Nahib and Jaka Suryanta, 2017 *IOP Conf. Ser.: Earth Environ. Sci.* 54012044, https://forest.assam.gov.in/information-services/territorial-wing
❖ Nath, Biswajit and Acharjee, Shukla, 2013, Forest Cover Change Detection using Normalized Difference Vegetation Index (NDVI) : A Study of Reingkhyongkine Lake's Adjoining Areas, Rangamati, Bangladesh, Indian Cartographer, Vol. XXXIII, 2013
❖ Medhi and Kar, 2016, "Depletion of Forest Cover and Encroachment in Gobinda Reserved Forest in the Goalpara District of Assam, India," Journal of Space and Culture , India 2016, 4:1 P-40 DOI: 10.20896/saci.v4i1.187
❖ Deka, S., Tripathi, O. P., & Paul, A. (2019). Perception-based assessment of ecosystem services of Ghagra Pahar forest of Assam, Northeast India. *Geology, Ecology, and Landscapes*, *3*(3), 197-209.
❖ Rabha, K. Bipul, Actual Picture of JFM System: Field Study from Goalpara District of Assam, International Journal of Research in Humanities and Social Studies, Volume 3, Issue 7, July 2016, PP 1-6 ISSN 2394-6288 (Print) & ISSN 2394-6296 (Online)
❖ Verma, P., Raghubanshi, A., Srivastava, P. K., & Raghubanshi, A. S. (2020). Appraisal of kappa-based metrics and disagreement indices of accuracy assessment for parametric and nonparametric techniques used in LULC classification and change detection. *Modeling Earth Systems and Environment*, *6*(2), 1045-1059.